

Solution to T1 by Waitz. (Unified Thermodynamics)

It is understood at this point in Unified that you have only had one or two lectures on thermodynamics, and no propulsion lectures. So what is expected is that you recognize conversions between various forms of energy when they occur and know the difference between transfers of energy called “work” and transfers of energy called “heat”.

- This is a neat process. I will describe it generally first, and then describe the energy exchange processes in more detail in the following bullets. The liquid fuel and oxidizer are pumped along the walls of the combustion chamber and rocket nozzle. They are used to cool the walls. In doing so, they pick-up energy and undergo a phase change to become gases. These higher energy gases are used to drive the liquid fuel and oxidizer pumps (like pulling yourself up by your bootstraps). Then the gases are injected into the combustion chamber where they react. Then they are accelerated through the nozzle.
- The liquid fuel and oxidizer enter the device with internal, kinetic and chemical energy.
- The pumps do work on the liquid fuels, raising the pressure and increasing the internal energy.
- These fuels then pass by the walls of the combustion chamber and nozzle where heat is transferred from the hot walls, increasing the internal energy of the fuels. There is a phase change (liquid to vapor).
- The higher energy gases then do work on the turbines that drive each turbopump. In the process, the gases lose internal and kinetic energy. If this process were ideal, all the energy would go into increasing the energy of the liquid fuels, but it is not ideal so there is typically some waste heat generated.
- The gases then enter the combustion chamber where they react, converting chemical energy into internal/thermal energy (very high temperature and pressure).
- The nozzle converts the high internal energy into high kinetic energy. In the process, some of the energy of the reacted gases near the walls is transferred to the walls (and then on to the fuels being used to cool the walls).
- Although the liquid fuels coming in have energy in several forms, and the gases leaving the nozzle have energy in several forms, the primary energy conversion for the device as a whole is the conversion of the chemical energy of the liquid fuels to kinetic energy of the propulsive gases.